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Effect of Some Growing Conditions on Productivity of Celery (*Apium graveolens* L. var. secalinum) Grown in Two Different Locations

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Abstract: Experiments were conducted through 2022/2023 and 2023/2024 seasons of to evaluate the growth and productivity of celery plants (*Apium graveolens* L. var. secalinum) grown at two different locations in Egypt: the research station of Ali Mubarak in El-Beheira Governorate and Arab El-Awamer research station in Assiut Governorate, during four transplanting dates: December, January, February, and March. Results revealed that plants grown in sandy soil at Ali Mubarak conditions showed greater growth than those grown in the calcareous sandy soil at El-Awamer conditions. Plant height increased by 24.20%, and the number of stalks increased by 11.93%. and yield increased 23.31%, as well as nitrogen (N), phosphorus (P), and potassium (K) contents being relatively higher in celery plants grown under Ali Mubarak conditions than in those grown under El-Awamer conditions. However, the highest amount of chlorophyll content was achieved with plants planted in March under El-Awamer conditions, which increased by 23.14%. The significantly highest essential oil content and transformation of hydrocarbons into oxygenated components, along with enhanced vitamin C and antioxidant activity, were obtained with plants grown in February under El-Awamer conditions. while the highest value of the phthalides component was obtained with plants grown under Ali-Mubarak with the last transplanting dates in March. It could be concluded that the optimal transplanting dates for achieving maximum yield and quality in the two studied locations were determined to be January. Furthermore, the Aly Mubarak site emerged as the premier location for celery production, while the Arab El-Awamer site yielded superior oil content and quality of celery plants.

Keyword: Antioxidants, calcareous soil, celery, locations, transplanting dates and vitamin C.

1. Introduction

Celery (*Apium graveolens* Linn) plant is a member of the Apiaceae family, can be either an annual or perennial plant. It is native to the Mediterranean and North African countries and has a wide distribution in northern temperate and high-altitude tropical regions because they thrive better in the cool weather of temperate regions **(Aćimović, 2017)**. Intense light reduces the growth rate of celery that prefers shade. The optimum conditions for growth of celery were humid, mild growing conditions and temperatures ranging between 15°C and 22°C **(Khalil *et al.*, 2015)**. Celery grows in all soil types except alkaline soils, so the best pH value in the soil should be between 5 and 7 (**Fazal and Singla, 2012)**. Also, the best weather conditions for celery production are in the coastal climate **(Carratù *et al.*, 2010)**. Celery is an herb that treats a variety of diseases Because of its great medicinal value (**Al-Snafi, 2014)**. It can be benefit as a diuretic and bile, for kidney stones, gland stimuli, appetite improvement, intestinal regulation, and nerve agitation prevention **(Khairullah *et al.*, 2021)**.

The genus *Apium* has about twenty famous species. *Apium graveolens* var. Secalinum Alef., one of the important plant varieties, is famous as leaf celery or golden celery, which has small, aromatic leaves, and used as a fresh spice in Asian cooking. All parts of this plant contain an essential oil. Essential oil content ranges from 0.09 to 0.43% in the leaves and 2–3% in the fruit **(Rożek *et al*., 2016).** As stated by **Sowbhagya *et al*. (2007) and Rożek *et al*. (2016)**, the major constituents of celery essential oil are limonene, α- and β-pinene, selinene, along with myrcene. The active substances of celery exhibit antiparasitic, antioxidant activity, antibacterial and antifungal **(Shad *et al*. 2011; Nagella *et al*. 2012 and Baananou *et al*. 2013,).** The characteristic odor of the oil is correlated to the presence of phthalide compounds, which are referred to as active compounds and are primarily responsible for celery's distinctive odor **(Macleod *et al*., 1988 and Orav *et al*., 2003).** Phthalide compounds show antitumor, larvicidal, nematicidal, and fungicidal activity **(Adelakun *et al*., 2021)**.

All environmental conditions, along with their myriad variables and the requisite parameters of soil type, temperature, and photoperiod for the various stages of plant development, are closely linked to geographical location and the timing of planting. Consequently, a comprehensive understanding of a crop's performance across diverse environmental conditions will inevitably illuminate its behavioral responses to such fluctuations, thereby facilitating the exploration of its genetic potential and ensuring the harmonious synchronization of growth and the formation of its diverse organs with the prevailing climatic conditions. Moreover, evaluating the quality and productivity of aromatic and medicinal plants at different ecosystems in Egypt is a top priority, particularly in light of the current global climate change issue and its detrimental effects on agriculture **(Amedie, 2013; Abd El-Wahab, 2015 and FAO, 2015)**.

The objective of this study was to find out the best soil texture, best weather conditions, and suitable transplanting date to produce maximum production of celery (*Apium graveolens* L. var. secalinum) crop with high quality.

2. Materials and Methods

2.1. Experimental site

Field experiments were executed during two sequential seasons, 2022/2023 and 2023/2024, on celery (*Apium graveolens* L. var. secalinum) at two different locations (sandy and sandy calcareous soil) with four transplanting dates (December, January, February, and March).

The experiment was carried out at Ali Mubarak [experimental farm, Agric. Res. Center (A.R.C.), Horticulture Research Institute located in Bustan area, El-Beheira Governorate, Egypt (coordinates latitude 33°30' 1.4"N, longitude 30°19' 10.9"E, and 21 m MSL)] representing sandy soil and Arab El-Awamer [experimental farm, Agric. Res. Center (A.R.C.), Horticulture Research Institute located in Assiut Governorate, Egypt (coordinates latitudes 27° 03"N and 31° 01' E with an elevation of 71 meters above sea level)] representing sandy calcareous soil. Meteorological readings of temperature (°C) at experimental sites during the growing seasons (2022, 2023 and 2024) obtained from Central Laboratory for Agricultural Climate-Agricultural Research Center (A.R.C.)- Egypt, and presented in Figure (1).

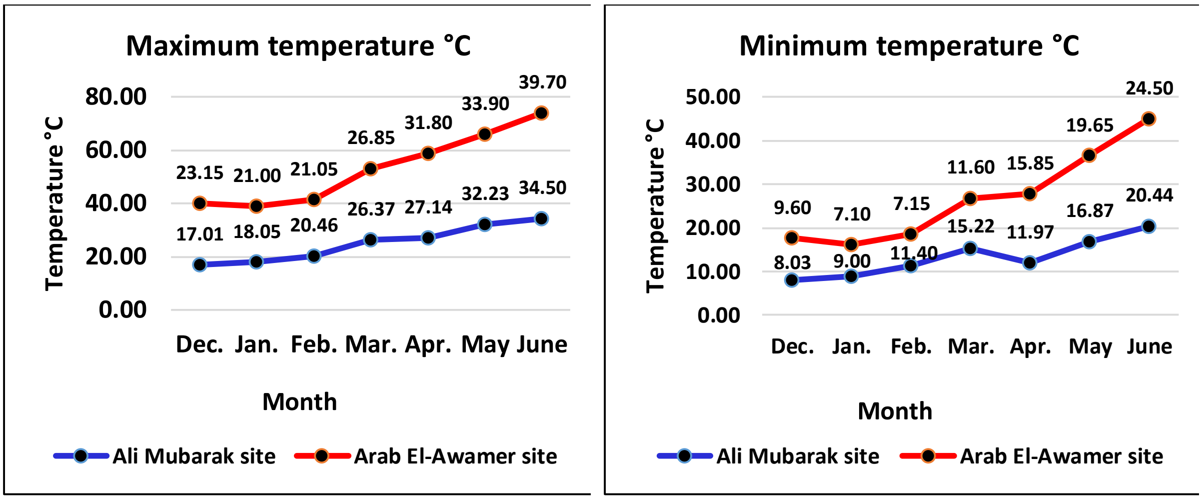

Fig. (1). Average monthly temperature (°C) conditions (max. and min.) during growth period (2022, 2023 and 2024).

Soil representative samples from two field experimental sites were collected at 0–30 cm of depth before planting and analyzing. The physical properties of soil experiments were determined according to **Israelsen and Hansen (1962),** the chemical properties were determined (**Chapman and Pratt, 1961)** and recorded in Table 1.

Table 1. Physico-chemical properties of the soil at two experimental sites

	Ali Mubarak site	**Arab El-Awammer site**
Physical properties		
Texture	Sandy	Sandy calcareous
Course sand (%)	96.49	90.91
Silt + clay (%)	2.51	9.09
Field Capacity, (%)	13.0	10.97
Wilting Point, (%)	4.6	4.45
Available water, (%)	8.3	6.4
Organic Matter %	0.5	0.4
Total $CaCO_3$ (%)	7.00	31.9
Bulk density (t/m^3)	1.69	1.63
Chemical properties		
EC(dS/m)	0.40	0.40
pH (1:2.5)	8.00	8.40

2.2. Plant material and agricultural practices

Apium graveolens L. var. Secalinum seeds were obtained from Agrimatco Agriculture Company, Administrative Building – Al-Karma 2 1st Neighborhood District Shikh Zayed, Egypt. Celery seeds were treated with a mycorrhizal and microbein mix and a fine mist of 10% sugar solution, then sown in trays in nursery conditions. 8-9 weeks later, the seedlings with three or four true leaves were transplanted in the field. Three replicates with a completely randomized block design were used to carry out the experiment. The seedlings were planted in plots under a drip irrigation system. Plots were 9 metre^2 (3 m wide by 3 m long), with 4 rows spaced 60 cm apart and hills spaced 25 cm apart (for a total of 44 plants per plot).

In both locations, soil preparation was applied by adding 200 kg superphosphate (12.5% P_2O_5)/fed. and 10 m³/fed. compost before transplanting, while the N and K were added with 200 kg ammonium sulphate (20.6% N)/fad. and 50 kg potassium sulphate (50% KO_2)/fad. in two equal portions after 30 and 45 days from transplanting for both fertilizers. Soluble fertilizers were dissolved in the fertilizer tank and applied by fertigation using this technique. Different cultural practices were applied according to the recommendations of the Agriculture Ministry.

The seedlings were planted in two experimental locations at four dates. Harvest was carried out three times, the first cut after 50-60 days of their transplanting and the second and third cuts after 21 days following the last cut on each transplanting date during the two growing seasons.

Transplanting dates, as follows:

- Transplanting in December - the base condition,
- Delaying the transplanting date by three weeks, i.e., to end of January,
- Delaying the transplanting date by six weeks, i.e., to mid of February and,
- Delaying the transplanting date by nine weeks, i.e., to first of March.

2.3. Data recorded

Plant height (cm), the number of branches per plant, the fresh and dry weights of aerial parts/plant (g), the fresh and dry weights of aerial parts/fed (ten), and the herb biomass/fed (ten) were all measures taken from randomly selected plants.

- Chlorophyll measurement: Chlorophyll determinations by Minolta SPAD-502 plus chlorophyll meter. The SPAD value for each leaf was derived from the average of tin measurements (5 from each side of the midrib of leaf), as computed by **León *et al*. (2007)**.

- Nitrogen, phosphorus, and potassium determination: The contents of nitrogen, phosphorus, and potassium in celery leaves were assessed via the methods of **Jackson (1967), Watanabe & Olsen (1965)** and **Brown & Lilleland (1946)**, respectively.

- Essential oil productivity: The **ASTA (1985)** method was used to determine the essential oil content of celery plants. Furthermore, essential oil kg/fed and oil yield/plant (ml) were also calculated. The major constituents of celery oil were determined in the second season of the experiment by gas chromatography.

- Gas chromatography analysis (GC) of celery essential oil: A Ds Chrom 6200 gas chromatograph technique containing a column BPX-5 and five phenyls (eq.) polysillphenylenesiloxane 0.25 x 30 mm ID x 0.25 µ film was employed to investigate the essential oil samples. The temperature program fluctuated between 60° and 200°C at the rate of 5°C every min. Air flowed at 300 ml/min, hydrogen at 30 ml/min, and nitrogen at 1 ml/min. The injector and detector had temperatures of 250°C and 300°C. Then the essential oil compounds comparing to those of authentic samples via their retention times were identification

- Antioxidant activity determination: Celery oil's antioxidant activity was assessed using the spectrophotometric test method of **Blos (1958)**, which uses the stable 2,2-diphenyl-1-picrylhydrazil (DPPH) radical as a reagent.

- Vitamin C: V.C. content was determined in filtered juice samples and expressed as mg ascorbic acid/100 ml fresh juice, as described by **A.O.A.C. (1999).**

2.4. Statistical analysis

In a two-way ANOVA analysis with a split-plot design, the locations as the main factor and transplanting dates as the sub-factor, three replicates were included, an analysis of variance (ANOVA) was conducted using the statistical software (Statisix 8), as advised by **Steel and Torrie (1980)**, the least significant difference (L.S.D. 0.05) test was used to evaluate differences between treatment means, with a probability level of 0.05.

3. Results and Discussion

Environmental conditions have direct and significant effects on celery (*Apium graveolens* L. var. secalinum) growth and development during the growing season, consequently, influencing yield and leaf essential oil and quality.

3.1. Effect of transplanting date on growth characteristics of celery plant in both locations

The influences of two distinct locations (Ali Mubarak and Arab El-Awamer) and varying transplanting dates on the height and stalk number of celery plants were examined across three harvests during two growing seasons (2022/2023 and 2023/2024), as illustrated in Tables 2 and 3. The findings clearly show that celery plants cultivated at the Ali Mubarak site exhibited a significant enhancement in growth traits compared to those cultivated at the Arab El-Awamer site. The highest mean values for plant height and stalk number (49.67 cm and 54.75 stalks per plant, respectively) were recorded in the second season for plants grown at the Ali Mubarak site. In contrast, the smallest plant height (35.58 cm) and the lowest mean stalk number (35.05 per plant) were noted in the first season for plants grown at the Arab El-Awamer site. The reason for the decrease in growth characteristics in plants grown in Arab El-Awamer conditions may be due to the warmer weather and/or the nature of the calcareous soil, which has low fertility, and the majority of nutritional components are not readily available, particularly phosphorus and micronutrients. Those deficiencies inhibit cell division, the metabolism of carbohydrates, the amount of soluble protein, and the accumulation of dry matter, according to **Lambers and Plaxton (2015)**. These results are agreeing with **Ghulam *et al.* (2012)**, who found decrease in lentil plant height (*Lens culinaris* L.) grown in calcareous soil without pressmud application, and also **Abu El-Leil *et al.* (2024)** mention that decreased micronutrients in marjoram result in shorter plants. In calcareous soils, plants suffering from not only Ca excess but also from low nutrient availability resulted from interactions with Ca and alkaline conditions **(Hartemink and Barrow, 2023)**. Crop deficiencies and low productivity result from calcareous soils with high pH and calcium carbonate concentration that struggle to maintain Ca homeostasis and reduced nutrient availability **(Brownrigg *et al.,* 2022)**.

In terms of the effect of transplanting date, the results showed that celery plant transplanting in January had the highest plants (50.40 and 52.53 cm) in the first cut in both cultivated seasons, respectively. Whatever, there were no significant differences between plants planted on the first and third transplanting dates (December and February), in this respect. While plants transplanted on the last date (March) recorded the lowest plant height (29.80 and 26.83 cm) in the third cut in both seasons, respectively. During 2023 growing season, transplanting in January obtained the higher stalk numbers (51.78, 57.61, and 64.07 stalks/plant in the first, second, and third cuts, respectively). Significantly lower stalk numbers (26.17, 32.00, and 34.17 stalks/plant for the first, second, and third cuts, respectively.) were obtained in March. The similar trend was shown during the 2024 growing season in the second and third cuts, while the first cut has no significant difference between the first and third dates.

Moreover, the interplay between various locations and transplanting dates was notably significant. The tallest plants (62.67 cm in the first cut of the first season and 57.00 cm in the second cut of the second season) and the maximum number of stalks (66.00 stalks per plant in the third cut for the first season, and 78.33 stalks per plant in the third cut for the second season) were observed in plants cultivated under the Ali Mubarak conditions in January date. Conversely, plants grown under the Arab El-Awamer conditions in March exhibited the shortest plants (26.33 cm in the third cut for the first season and 27.00 cm in the third cut for the second season), and the least number of stalks (24.00 and 28.67 stalks per plant in the first cut for the first and second seasons, respectively). In such locations, celery crops subjected to warmer conditions had a negative effect on growth characteristics during both seasons.

Table (2). Effect of transplanting date of celery on plant height (cm) in both locations

First season (2022/2023)									
Cuts	**First cut**			**Second cut**			**Third cut**		
Date Site	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**
December	46.00 b	39.18 c	**42.59 b**	40.00 bc	39.00 c	**39.50 b**	45.00 b	35.00 c	**40.00 b**
January	62.67 a	38.13 cd	**50.40 a**	54.00 a	43.24 b	**48.62 a**	56.00 a	44.33 b	**50.17 a**
February	47.67 b	39.33 c	**43.50 b**	40.33 bc	37.67 c	**39.00 b**	38.33 c	36.67 c	**37.50 b**
March	34.67 d	37.33 cd	**36.00 c**	31.67 d	33.33 d	**32.50 c**	27.33 d	26.33 d	**26.83 c**
Mean (A)	**47.75 a**	**38.50 b**		**41.50 a**	**38.31 b**		**41.67 a**	**35.58 b**	
LSD (0.05)									
A	**1.89**			**1.71**			**2.01**		
B	**2.68**			**2.42**			**2.85**		
A X B	**3.79**			**3.42**			**4.03**		
Second season (2023/2024)									
Cuts	**First cut**			**Second cut**			**Third cut**		
Date Site	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**
December	50.00 bc	42.14 de	**46.07 b**	45.00 bc	41.30 cd	**43.15 b**	48.67 b	36.00 de	**42.33 b**
January	56.67 a	48.37 c	**52.53 a**	57.00 a	42.58bcd	**49.79 a**	52.67 a	42.33c	**47.50 a**
February	52.00 b	43.00 d	**47.50 b**	46.67 b	40.00 d	**43.33 b**	44.00 c	38.00 d	**41.00 b**
March	40.00 de	39.33 e	**39.67 c**	34.33 e	36.00 e	**35.17 c**	32.67 e	27.00 f	**29.80 c**
Mean (A)	**49.67 a**	**43.21 b**		**45.75 a**	**39.97 b**		**44.50 a**	**35.83 b**	
LSD (0.05)									
A	**1.50**			**1.98**			**1.84**		
B	**2.13**			**2.81**			**2.60**		
A X B	**3.00**			**3.97**			**3.67**		

* S1= Ali Mubarak site (sandy soil), S 2 = Arab El-Awamer site (calcareous soil). Means followed by the different letters within columns for locations and rows for transplanting dates are significantly different based on the L.S.D. at P ≤ 0.05.

Table (3). Effect of transplanting date of celery on stalk number in both locations

First season (2022/2023)									
Cuts	**First cut**			**Second cut**			**Third cut**		
Date Site	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**
December	33.00 cd	32.00 d	**32.50 c**	40.85 e	36.35 f	**38.60 c**	49.00 bc	46.35 c	**47.68 c**
January	53.96 a	49.60 b	**51.78 a**	60.33 a	54.89 b	**57.61 a**	66.00 a	62.14 a	**64.07 a**
February	36.25 c	34.58 cd	**35.42 b**	47.67 c	44.00 d	**45.83 b**	52.33 b	49.55 bc	**50.94 b**
March	28.33 e	24.00 f	**26.17 d**	35.00 f	29.00 g	**32.00 d**	36.00 d	32.33 d	**34.17 d**
Mean (A)	**37.89 a**	**35.05 b**		**45.96 a**	**41.06 b**		**50.83 a**	**47.60 b**	
LSD (0.05)									
A	**1.69**			**1.32**			**1.99**		
B	**2.39**			**1.87**			**2.82**		
A X B	**3.38**			**2.65**			**3.99**		
Second season (2023/2024)									
Cuts	**First cut**			**Second cut**			**Third cut**		
Date Site	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**
December	46.33 b	33.00 cd	**39.67 b**	44.67 c	38.33 d	**41.50 c**	47.33 d	43.33 e	**45.83 c**
January	54.27 a	52.60 a	**53.44 a**	60.67 a	55.33 b	**58.00 a**	78.33 a	72.48 b	**75.41 a**
February	36.33 c	43.33 b	**39.83 b**	46.67 c	44.13 c	**45.40 b**	51.00 c	53.00 c	**52.00 b**
March	30.33 de	28.67 e	**29.50 c**	37.67 d	33.00 e	**35.34 d**	42.33 e	38.00 f	**40.17 d**
Mean (A)	**41.82 a**	**39.40 b**		**47.42 a**	**42.70 b**		**54.75 a**	**51.70 b**	
LSD (0.05)									
A	**2.06**			**1.98**			**1.77**		
B	**2.91**			**2.80**			**2.50**		
A X B	**4.12**			**3.96**			**3.54**		

* S1= Ali Mubarak site (sandy soil), S2 = Arab El-Awamer site (calcareous soil). Means followed by the different letters within columns for locations and rows for transplanting dates are significantly varies based on the L.S.D. at P ≤ 0.05.

2.2. Effect of transplanting date on biomass accumulation of celery plants in both locations

Effect of different locations and transplanting dates on biomass accumulation of celery plants for three cuts was recorded and presented in tables 4, 5 and 6. The results indicated that different locations affected the biomass accumulation of celery plants. The plants cultivated in the Ali Mubarak site recorded the highest fresh weight/plant (177.81 and 198.01 g/plant) in third cut through the growing seasons, respectively (Table, 4), and fresh weight/fed (3.47 and 3.86 ten. /fed.) in third cut through first and second seasons, respectively. This was reflected in the herb biomass yield/fed. (Table, 6), which had the highest yield (9.71 and 10.74 ten. /fed. In the first and second seasons, respectively). While the plants cultivated in Arab El-Awamer site recorded the lower fresh weight/plant (115.24 and 130.49 g/plant) in first cut through first and second seasons, respectively, and fresh weight/fed (2.25 and 2.55 ten. /fed.) in first cut through first and second seasons.

Table (4). Effect of transplanting date of celery on fresh weight/plant (g) in both locations

First season (2022/2023)									
Cuts	**First cut**			**Second cut**			**Third cut**		
Date Site	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**
December	157.48 c	142.08 d	**149.78 b**	150.33d	132.47 e	**141.40c**	158.19d	133.33 e	**145.76 c**
January	199.00 a	150.08 cd	**174.54 a**	227.74a	200.76 b	**214.25a**	295.89 a	252.33 b	**274.11 a**
February	174.28 b	115.13 e	**144.71 b**	189.33b	169.00 c	**179.17b**	191.67 c	160.41d	**176.04b**
March	91.67 f	53.65 g	**72.66 c**	90.00 f	62.58 g	**76.29 d**	65.49 f	53.67 f	**59.58 d**
Mean (A)	**155.61 a**	**115.24 b**		**172.52a**	**142.87 b**		**177.81 a**	**149.94 b**	
LSD (0.05) A B A X B	**6.26 8.86 12.53**			**6.54 9.25 13.09**			**6.27 8.86 12.54**		
Second season (2023/2024)									
Cuts	**First cut**			**Second cut**			**Third cut**		
Date Site	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**
December	155.00 c	140.08 d	**147.54 c**	181.13d	166.67de	**173.90c**	198.33 c	120.37 e	**159.35 c**
January	209.67 a	184.42 b	**197.04 a**	282.24a	236.67 b	**259.45a**	324.22 a	291.67 b	**307.94 a**
February	187.62 b	160.46 c	**174.04 b**	215.00c	154.76 e	**184.88b**	182.33 d	178.04d	**178.04b**
March	97.67 e	36.99 f	**67.33 d**	83.33 f	62.58 g	**72.96 d**	87.16 f	58.33 g	**72.75 d**
Mean (A)	**162.49 a**	**130.49 b**		**190.43a**	**155.17 b**		**198.01 a**	**161.03 b**	
LSD (0.05) A B A X B	**6.06 8.56 12.11**			**7.32 9.36 13.65**			**6.87 9.71 13.73**		

S1= Ali Mubarak site (sandy soil), S2 = Arab El-Awamer site (calcareous soil). Means followed by the different letters within columns for locations and rows for transplanting dates are significantly varies based on the L.S.D. at $P \leq 0.05$.

The effect of transplanting dates showed highly significant effects on fresh weight/plant and per fed, which led to highly morally significant effects on the yield during both seasons. The highest fresh weight (307.94 g/plant and 6.01 ten. /fed.) was obtained in third cut by transplanting celery in January during the 2023/2024 season, while the lowest fresh weight (59.58 g/plant and 1.16 ten. /fed.) was observed in third cut by transplanting celery at the late transplanting date (March). While there is no significant effect between first date and third date. The similar trend was obtained through the 2022/2023 season with a significant effect between all transplanting dates (Tables 4 and 5).

Table (5). Effect of transplanting date of celery on fresh weight/fed (ten) in both locations

First season (2022/2023)									
Cuts	**First cut**			**Second cut**			**Third cut**		
Date / Site	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**
December	3.07 c	2.77 d	**2.92 b**	2.93 d	2.58 e	**2.76 c**	3.83 d	2.60 e	**2.84 c**
January	3.88 a	2.93 cd	**3.40 a**	4.44 a	3.91 b	**4.18 a**	5.77 a	4.92 b	**5.35 a**
February	3.41 b	2.25 e	**2.83 b**	3.69 b	3.30 c	**3.50 b**	3.74 c	3.13 d	**3.43 b**
March	1.79 f	1.05 g	**1.42 c**	1.76 f	1.22 g	**1.49 d**	1.28 e	1.05 f	**1.16 d**
Mean (A)	**3.04 a**	**2.25 b**		**3.21 a**	**2.75 b**		**3.47 a**	**2.92 b**	
LSD (0.05)									
A	**0.12**			**0.13**			**0.12**		
B	**0.17**			**0.18**			**0.17**		
A X B	**0.25**			**0.27**			**0.24**		
Second season (2023/2024)									
Cuts	**First cut**			**Second cut**			**Third cut**		
Date / Site	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**
December	3.02 c	2.73 d	**2.88 c**	3.53 d	3.25 de	**3.39 c**	3.87 c	2.35 e	**3.11 c**
January	4.09 a	3.60 b	**3.84 a**	5.51 a	4.62 b	**5.06 a**	6.32 a	5.69 b	**6.01 a**
February	3.66 b	3.13 c	**3.40 b**	4.19 c	3.02 e	**3.61 b**	3.56 d	3.39 d	**3.47 b**
March	1.91 e	0.72 f	**1.31 d**	1.63 f	1.22 g	**1.42 d**	1.70 f	1.14 g	**1.42 d**
Mean (A)	**3.17 a**	**2.55 b**		**3.72 a**	**3.03 b**		**3.86 a**	**3.14 b**	
LSD (0.05)									
A	**0.12**			**0.14**			**0.13**		
B	**0.17**			**0.20**			**0.19**		
A X B	**0.24**			**0.29**			**0.27**		

* S1= Ali Mubarak site, S2 = Arab El-Awamer site. Means followed by the different letters within columns for locations and rows for transplanting dates are significantly varies based on the L.S.D. at $P \leq 0.05$.

The reason for the decrease in growth characteristics and biomass accumulation in plants planted on the last transplanting date (March) may be due to the high temperature during the growth period, which negatively affected all growth trials that were studied (Fig. 1) compared with second transplanting date (January).

All transplanting dates achieved a normal herb biomass yield except the second date, which had the maximum yield (12.93 and 14.91 ten. /fed.) observed with plants planted in January in both seasons, respectively. Contrariwise, minimum yield (4.07 and 4.16 ten. /fed) notably by the last date (March), through the two growing seasons (table 6).

Table (6). Effect of transplanting date of celery on herb biomass of yield/fed. (ten.) in both locations.

Season	**First season (2022/2023)**			**Second season (2023/2024)**		
Date / Site	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**
December	9.09 d	7.95 e	**8.520 c**	10.42 d	8.33 f	**9.37 c**
January	14.09 a	11.76 b	**12.93 a**	15.91 a	13.90 b	**14.91 a**
February	10.83 c	8.67 d	**9.75 b**	11.41 c	9.54 e	**10.47 b**
March	4.82 f	3.31 g	**4.07 d**	5.23 g	3.08 h	**4.16 d**
Mean (A)	**9.71 a**	**7.92 b**		**10.74 a**	**8.71 b**	
LSD (0.05)						
A	**0.21**			**0.29**		
B	**0.30**			**0.42**		
A X B	**0.43**			**0.59**		

S1= Ali Mubarak site (sandy soil), S2 = Arab El-Awamer site (calcareous soil). Means followed by the different letters within columns for locations and rows for transplanting dates are significantly varies based on the L.S.D. at $P \leq 0.05$.

The combined effects of location, transplanting dates, and time of harvest are displayed in Tables 4, 5, and 6. Locations and transplanting dates interacted to significantly affect fresh weight/plant, per fed., and the majority of the yield in the both growing seasons. The maximum value of fresh weight/plant, per fed. (324.22 g/plant and 6.32 ten. /fed.), was obtained in the third cut with plants implanted into Ali Mubarak site in January during the 2023/2024 growing season, while the minimum value of fresh weight/plant and per fed. (36.99 g/plant and 0.72 ten. /fed.), was obtained in first cut with plants that were implanted into Arab El-Awamer site on last date (March) during the 2023/2024 growing season. Generally, the total yield of celery crop obtained in our study was nearly similar to the resulting celery yield that was obtained by **Rożek (2007) and Maharik and Mancy (2017).** Whatever, these obtained variations in celery productivity in different sites may be attributed to the presence of a diverse array of weather conditions in the two sites that were examined. At the Ali Mubarak site, there was an elevating in the yield parameters accompanying the reduction of air temperature and solar radiation and increasing relative humidity average (Tables 1). The rate of plant development is a function of temperature and typically increases linearly from decreased temperature to the optimal temperature, according to **Roberts and Summerfield (1987)**, who got similar results. **Kintzios (2003) and Khalil *et al.* (2015)** state that celery grows best in moderate, humid environments and that the ideal temperature range for this plant is roughly 15℃ to 22℃., therefore, the higher productivity was obtained in temperate regions under cool weather. According to **Khalil *et al*. (2015)**, further warming inhibits the rate of development in celery. Moreover, **Atkinson and Porter (1996)** mention that physical environmental factors, such as temperature and radiation, influence the growth and development of plants; temperature influences the growth of plants themselves by affecting enzyme activity or membrane behavior. Consequently, It has a significant effect on respiration and assimilation and translocation processes but little effects on the rate of photosynthesis process at low light levels or light saturation. Subsequently, the spectral composition of light influences development processes.

2.3. Effect of transplanting date on dry matter of celery plant in both locations.

The dry matter yield of celery was significantly varied under the influence of location and transplanting date, according to tables 7 and 8.

The highest yield of dry matter (36.69 and 40.82 g/plant and 0.72 and 0.80 ten/fed.) was from plants instilled in Ali Mubarak site in the third cut for two seasons, respectively. The lowest yield of dry matter (21.35 and 24.06 g/plant and 0.42 and 0.47 ten/fed.) was from plants instilled in Arab El-Awamer site in the first cut for the two cultivated seasons, respectively.

The interaction between the effect of location and transplanting date showed that the highest accumulation of dry matter was gained in plants cultivated in January, with no significant difference between the two sites in the second and third cuts during both seasons. While in the first cut, plants had a significant difference between two sites (tables 7 and 8).

3.4. Effect of transplanting date of celery on leaf SPAD value in both locations

Data in table (9) showed that differences in leaf SPAD value were observed at different planting date of celery in both locations. Whatever, leaf SPAD value of plants planted in the Arab El-Awamer site was significantly higher than in the Ali Mubarak site in all cuts at the same transplanting date. The highest value was recorded (45.41 and 45.77) in Arab El-Awamer site in the third cut for the two growing seasons, respectively. This may be attributed to the high temperatures and sunlight at this time in both locations (Fig. 1). Regarding the effect of planting date, chlorophyll content expressed as leaf SPAD value were affected by delaying in planting date, transplanting in March leading to increasing leaf SPAD value in the celery plant in both seasons (45.13 and 48.57, respectively) in the third cut. However, early transplanting time (December) in both seasons led to decreasing leaf SPAD value (34.76 and 33.14, respectively) in the third cut comparing to the last date.

Table (7). Effect of transplanting date of celery on dry weight/plant (g) in both locations

First season (2022/2023)									
Cuts	**First cut**			**Second cut**			**Third cut**		
Date Site	**S 1**	**S 2**	**Mean(B)**	**S 1**	**S 2**	**Mean(B)**	**S 1**	**S 2**	**Mean(B)**
December	28.16 cd	26.60 d	**27.38 b**	28.14 cd	26.39 d	**27.27 c**	31.19 c	28.96 c	**30.08 c**
January	36.30 a	29.90 c	**33.10 a**	42.63 a	41.60 a	**42.12 a**	58.94 a	57.83 a	**58.39 a**
February	32.69 b	18.93 e	**25.81 b**	37.72 b	29.02 c	**33.37 b**	41.63 b	30.17 c	**35.90 b**
March	18.26 e	9.98 f	**14.12 d**	18.65 e	12.23 f	**15.44 d**	15.01 d	11.19 e	**13.10 d**
Mean (A)	**28.85 a**	**21.35 b**		**31.78 a**	**27.31 b**		**36.69 a**	**32.04 b**	
LSD(0.05)									
A	**1.16**			**1.27**			**1.26**		
B	**1.65**			**1.79**			**1.79**		
A X B	**2.33**			**2.54**			**2.53**		
Second season (2023/2024)									
Cuts	**First cut**			**Second cut**			**Third cut**		
Date Site	**S 1**	**S 2**	**Mean(B)**	**S 1**	**S 2**	**Mean(B)**	**S 1**	**S 2**	**Mean(B)**
December	27.72 c	26.22 c	**26.97 c**	33.91 d	33.20 d	**33.55 b**	39.11 b	26.14 d	**32.63 c**
January	38.25 a	36.74ab	**37.49 a**	52.84 a	49.04 b	**50.94 a**	64.58 a	66.85 a	**65.72 a**
February	35.12 b	26.39 c	**30.76 b**	42.83 c	26.57 e	**34.70 b**	39.60 b	32.68 c	**36.14 b**
March	19.46 d	6.88 e	**13.17 d**	17.27 f	12.23 g	**14.75 c**	20.00 e	12.16 f	**16.07 d**
Mean (A)	**30.14 a**	**24.06 b**		**36.71 a**	**30.26 b**		**40.82 a**	**34.46 b**	
LSD(0.05)									
A	**1.12**			**1.36**			**1.50**		
B	**1.58**			**1.92**			**2.12**		
A X B	**2.24**			**2.72**			**3.00**		

* S1= Ali Mubarak site (sandy soil), S2 = Arab El-Awamer site (calcareous soil). Means followed by the different letters within columns for locations and rows for transplanting dates are significantly varies based on the L.S.D. at P ≤ 0.05.

Table (8). Effect of transplanting date of celery on dry weight/fed (ten) in both locations

First season (2022/2023)									
Cuts	**First cut**			**Second cut**			**Third cut**		
Date Site	**S 1**	**S 2**	**Mean(B)**	**S 1**	**S 2**	**Mean(B)**	**S 1**	**S 2**	**Mean(B)**
December	0.55 cd	0.52 d	**0.54 b**	0.55 cd	0.51 d	**0.53 c**	0.61 c	0.56 c	**0.59 c**
January	0.71 a	0.58 c	**0.64 a**	0.83 a	0.81 a	**0.82 a**	1.15 a	1.30 a	**1.14 a**
February	0.64 b	0.37 e	**0.50 b**	0.64 b	0.57 c	**0.65 b**	0.81 b	0.59 c	**0.70 b**
March	0.36 e	0.19 f	**0.28 c**	0.36 e	0.24 f	**0.31 d**	0.29 d	0.22 e	**0.25 d**
Mean (A)	**0.56 a**	**0.42 b**		**0.62 a**	**0.53 b**		**0.72 a**	**0.63 b**	
LSD (0.05)									
A	**0.02**			**0.02**			**0.03**		
B	**0.03**			**0.03**			**0.04**		
A X B	**0.05**			**0.05**			**0.05**		
Second season (2023/2024)									
Cuts	**First cut**			**Second cut**			**Third cut**		
Date Site	**S 1**	**S 2**	**Mean(B)**	**S 1**	**S 2**	**Mean(B)**	**S 1**	**S 2**	**Mean(B)**
December	0.54 c	0.51 c	**0.53 c**	0.66 d	0.65 d	**0.51 b**	0.76 b	0.51 d	**0.64 c**
January	0.74 a	0.71 ab	**0.73 a**	1.03 a	0.95 b	**0.83 a**	1.26 a	1.30 a	**1.28 a**
February	0.69 b	0.51 c	**0.60 b**	0.84 c	0.52 e	**0.66 b**	0.77 b	0.64 c	**0.71 b**
March	0.38 d	0.13 e	**0.26 d**	0.34 f	0.24 g	**0.37 c**	0.39 e	0.24 f	**0.31 d**
Mean (A)	**0.59 a**	**0.47 b**		**0.72 a**	**0.59 a**		**0.80 a**	**0.67 a**	
LSD (0.05)									
A	**0.02**			**0.03**			**0.03**		
B	**0.03**			**0.04**			**0.04**		
A X B	**0.04**			**0.05**			**0.06**		

*S1= Ali Mubarak site (sandy soil), S2 = Arab El-Awamer site (calcareous soil). Means followed by the different letters within columns for locations and rows for transplanting dates are significantly varies based on the L.S.D. at P ≤ 0.05.

Table (9). Effect of transplanting date of celery on leaf SPAD value in both locations

First season (2022/2023)									
Cuts	**First cut**			**Second cut**			**Third cut**		
Date Site	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**
December	29.63 d	32.67 cd	**31.15 b**	31.70 e	33.63 de	**32.67 c**	33.67 d	35.85 d	**34.76 c**
January	30.87cd	35.30 bc	**33.08 b**	37.15 bc	39.67 b	**38.41 b**	42.30 c	45.63 bc	**43.97 ab**
February	36.07bc	40.33 ab	**38.20 a**	35.00 cd	40.33 b	**37.67 b**	36.80 d	46.71 b	**41.75 b**
March	38.93ab	42.60 a	**40.77 a**	38.53 b	46.95 a	**42.74 a**	36.80 d	53.47 a	**45.13 a**
Mean (A)	**33.88 b**	**37.73 a**		**35.60 b**	**40.15 a**		**37.39 b**	**45.41 a**	
LSD (0.05) **A** **B** **A X B**	**2.73** **3.86** **5.46**			**1.63** **2.30** **3.26**			**1.82** **2.58** **3.65**		
Second season (2023/2024)									
Cuts	**First cut**			**Second cut**			**Third cut**		
Date Site	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**
December	33.27 d	35.00 cd	**34.13 b**	32.22 d	34.47 d	**33.34 c**	32.43 d	33.85 d	**33.14 c**
January	32.60 d	36.30 cd	**34.45 b**	33.82 d	43.00 b	**38.41 b**	35.97 d	45.53 bc	**40.75 b**
February	36.40cd	43.67 ab	**40.03 a**	35.00 d	44.33 b	**39.67 b**	36.80 d	50.04 ab	**43.42 b**
March	39.40bc	45.60 a	**42.50 a**	39.20 c	47.62 a	**43.41 a**	43.47 c	53.67 a	**48.57 a**
Mean (A)	**35.42 b**	**40.14 a**		**35.06 b**	**42.35 a**		**37.17 b**	**45.77 a**	
LSD (0.05) **A** **B** **A X B**	**2.26** **3.19** **4.52**			**1.61** **2.28** **3.22**			**2.47** **3.49** **4.94**		

*S1= Ali Mubarak site (sandy soil), S2= Arab El-Awamer site (calcareous soil). Means followed by the different letters within columns for locations and rows for transplanting dates are significantly varies based on the L.S.D. at P ≤ 0.05.

3.5. Effect of transplanting date of celery on NPK in both locations

Data illustrated in Fig. 2 showed the effect of two locations and different transplanting dates on nitrogen, phosphorus, and potassium (NPK) content of leaf celery during 2023/2024 cultivated season. The result appeared that N, P, and K contents in celery plant relatively higher in plants grown in Ali Mubarak site) sandy soil) than those grown in Arab El Awamer site (sandy calcareous soil) . The results in the same figure also indicated that the nitrogen, phosphorus, and potassium (NPK) content in celery leaves increased when the transplanting date was delayed, with February transplanting showing significantly higher levels of nitrogen, phosphorus, and potassium (3.20, 0.89, and 0.07%, respectively) at Ali Mubarak site. Whatever the highest N, P and K content in plants grown in Arab El Awamer site was observed in those transplanted in January date. The decrease in content of NPK was due decrease in yield and dry matter production of celery that may due to delaying of transplanting date and/ or soil composition (Table 1). The higher content of this nutrient in celery grown in sandy soil was due a higher production component compared with that in the plants grown in sandy calcareous soil.

The content of N, P and K decreased significantly with increased in calcium carbonate because, the majority of nutritional components are not readily available, particularly phosphorus and micronutrients. Calcareous soil chemical processes affect the deposition or assimilation of nutrients, the chemistry and abundance of N, P, K, and micronutrients, and also the pH of the soil effect on the availability of nutrients (**Wassif & Wassif, 2021**). The higher concentrations of calcium carbonate ($CaCo_3$) in the calcareous soils resulted in increase the soil's P buffer capacity, and also stable Calcium phosphates resulted from the precipitation reactions **(Brownrigg *et al.*, 2022).** The higher temperature in February (Fig. 1) may be the reason for the increased absorption of elements from the soil, while, the rise in temperatures, increase the flow of cytosol in the plant wood. The effect of rise of temperature on $CaCO_3$ is complex, because it involves abiotic and biotic factors, and also rising temperatures decrease the solubility of $CaCO_3$ and CO_2 but increase soil respiration, (**Bontpart *et al.*, 2024).**

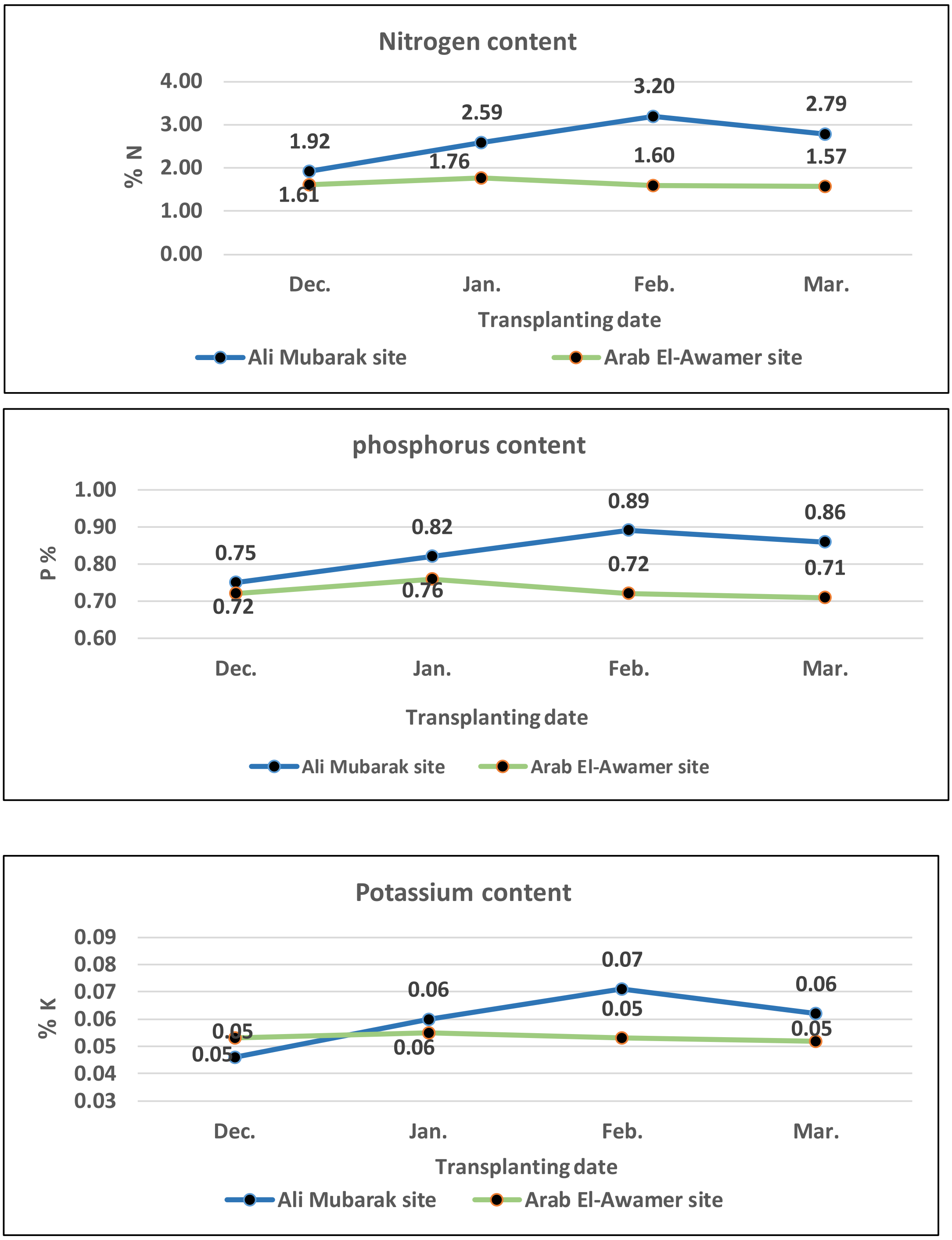

Fig. (2). Effect of transplanting date on celery NPK content in both locations

3.6. Effect of transplanting date on celery essential oil content in both locations

Celery leaves' essential oil content was significantly affected by location at all dates during the growing season (Table 10). The highest essential oil content (0.07%) was registered in second cut at Arab El-Awamer in the southern location (Assuit Governorate) of Egypt. On the other side, the lowest essential oil content (0.05%) was registered in the northern location (Ali Mubarak) of Egypt.

Notably, the temperate climate and a optimum humidity during all times of harvest, leading to increasing essential oil contents being recorded (0.10%) in plants grown under Arab El-Awamer conditions in February and harvested in April, followed by 0.09% in January and harvested in April. The differences were significant between the different weathers at transplanting dates. In this study, the two locations' varying weather and planting dates resulted in notable variations in oil content. Celery leaves' essential oil content is mostly influenced by the growth season's environmental factors. These factors can raise essential oil content by as much as double **(Rożek, 2007)**. The changes in essential oil content are related to plant varieties and also to weather conditions during the period of growth and development of plant **(Rożek *et al.*, 2016)**.

Generally, essential oil content increased along with the country's solar radiation and warmth climate (air temperature) and particularly in the southern location (Arab El-Awamer site), where these factors are elevated. The differences were significant between the different weathers at transplanting dates. They can cause the oil content to rise by as much as double **(Rożek *et al.*, 2016)**. These results were in the same line with **Abd El-Wahab *et al.* (2016)**, who described the warmth of climate and increasing atmospheric humidity increasing the essential oil content in the geranium plant.

Table (10). Effect of transplanting date of celery on essential oil content in both locations

Season (2023/2024)									
Cuts	**First cut**			**Second cut**			**Third cut**		
Date Site	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**	**S 1**	**S 2**	**Mean (B)**
December	0.03 f	0.03 e	**0.03 c**	0.03 e	0.04 e	**0.03d**	0.05 e	0.06 d	**0.05 c**
January	0.05cd	0.06 b	**0.06 b**	0.07 c	0.08 b	**0.07b**	0.08 b	0.09 a	**0.08 a**
February	0.05 d	0.08 a	**0.07 a**	0.08 b	0.10 a	**0.09a**	0.06 d	0.07 c	**0.06 b**
March	0.06 c	0.06 b	**0.06 b**	0.05 d	0.05 d	**0.05 c**	0.05 d	0.04 f	**0.04 d**
Mean (A)	**0.04 a**	**0.06 b**		**0.06 b**	**0.07 a**		**0.06 a**	**0.06 a**	
LSD(0.05) A B A X B	** 0.022 0.031 0.044**			** 0.043 0.060 0.086**			** 0.030 0.042 0.059**		

*S1= Ali Mubarak site (sandy soil), S2= Arab El-Awamer site (calcareous soil). Means followed by the different letters within columns for locations and rows for transplanting dates are significantly varies based on the L.S.D. at $P \leq 0.05$.

3.6. Effect of transplanting dates on celery oil productivity in both locations

The composition of celery leaf oil was affected by different transplanting dates in two experimental sites (tables 11 and 12). In total, 24 constituents were identified in celery oil in different locations and transplanting dates and listed in Table 11. Hydrocarbon terpenes comprised the majority of the celery oil aroma (ranging from 32.93 to 94.58%). The maximum hydrocarbon terpenes were found in plants that were planted in January in both sites. Limonene and myrcene are the dominant monoterpene components of celery essential oil. The highest biosynthesis of limonene (57.18%) was found in leaf oil in January in Ali-Mubarak conditions, where low temperatures (max. 27.14°C and min. 11.97°C) were recorded. On the contrary, higher temperatures (max. 31.8°C and min. 15.85°C) in Arab El-Awamer at the same transplanting date led to decreased limonene biosynthesis (47.16%). The lowest percentage of limonene (9.78%) was found on the following date in the Arab El-Awamer condition. The results of the previous study show the limonene concentration is most clearly dependent on genetic and environmental factors **(Orav *et al.*, 2003 and Olle and Bender, 2010).** Moreover, **Watts *et al.* (1984)** found that in celery plant, exposing cells to temperatures of 25°C resulted in the release of phthalides and other terpenoids, i.e., limonene, into the medium.

The maximum oxygenated compounds (67.06%) were found in plants that were planted in February at the Arab El-Awamer site, may be due to the Arab El-Awamer conditions in February, caused monoterpene or sesquiterpene hydrocarbons to begin to decrease and sped up the transformation of hydrocarbons into oxygenated components.

Other hydrocarbon compounds include α-pinene, γ-terpinene, sabinene, ocimene, and selinene. And oxygenated compounds, including camphene, β-caryophyllene, humulene, and kessane, identified in this investigation were also detected in varying proportions depending on different locations. The result agrees with many other studies in **Orav *et al*. (2003) and Rożek *et al*. (2016).**

Table (11). Effect of transplanting date of celery on essential oil composition in both locations through 2023/2024 season

Site	Ali-Mubarak site				Arab El-Awamer site			
Date / Compounds	Dec.	Jan.	Feb.	Mar.	Dec.	Jan.-	Feb.	Mar.
Hydrocarbon terpenes								
α–Pinene	-	-	-	-	1.17	0.18	-	-
Sabinene	-	-	-	-	-	0.59	-	-
Myrcene	17.31	25.84	27.32	16.50	25.99	38.27	7.79	22.44
Limonene	41.89	57.18	43.94	37.12	42.82	47.16	9.78	43.98
Ocimene	-	-	-	-	-	-	15.36	-
γ-Terpinene	-	-	2.56	-	-	2.25	-	-
β-Elemene	-	-	-	-	4.91	-	-	1.66
(E)-β-caryophyllene	5.04	3.81	5.89	-	3.79	2.94	-	1.75
Calamenene	-	-	-	-	1.48	0.39	-	-
α-selinene	7.58	7.75	6.91	4.09	3.68	2.38	-	-
Humulene	-	-	-	-	1.20	-	-	-
Germacrene	-	-	-	-	2.61	-	-	3.60
Trans- guaiene	5.38	-	0.68	7.25	-	-	-	-
Farnesene	-	-	-	-	-	0.91	-	-
Oxygenated terpenes								
4,4-lsopropylidene diphenol	-	-	-	-	-	-	12.59	-
Trans– limonene oxide	-	-	-	-	-	0.34	-	-
Butylphthalide	-	1.02	0.91	-	6.57	1.40	trace	-
Terpinen-4-ol	-	-	1.23	-	-	-	-	-
Phytyl acetate 338	5.21	-	-	-	-	-	-	-
Kessane	-	-	-	-	-	0.29	42.79	6.99
Sedanenolide	13.80	4.4	3.70	15.31	3.68	-	-	16.87
Apiol	2.37	-	3.31	19.72	-	0.59	4.64	-
Caryophyllene oxide	-	-	-	-	-	2.30	7.04	1.69
Dihydroagarofuran	1.42	-	3.55	-	2.08	-	-	1.02
Hydrocarbon terpenes	**77.20**	**94.58**	**87.30**	**64.96**	**87.65**	**95.07**	**32.93**	**73.43**
Oxygenated terpenes	**22.80**	**5.42**	**12.70**	**35.03**	**12.33**	**4.92**	**67.06**	**26.57**
Total	**100**	**100**	**100**	**99.99**	**99.98**	**99.99**	**99.99**	**100**

3.7. Change of Phthalide compounds as affected by transplanting date in both locations

The amount of phthalide compounds in the aroma of celery plants changed depending on where they were grown and when they were transplanted (Table, 12).

The conditions of Ali-Mubarak were superior, exhibiting a higher content of these compounds in all studied transplanting dates compared to those of Arab El-Awamer. Ali-Mubarak's condition led to an accumulated total phthalide on celery leaves planted in March, which recorded 35.03%. In this study, sedanenolide, apiol, and butylphthalide compounds were identified in all treatments, but varied in their contribution to the composition. Sedanenolide and apiol are found in celery plants grown in March; the highest proportions (15.31 and 19.72%, respectively) were found in the Ali-Mubarak site, while the highest percentage (16.87%) of sedanenolide was recorded in March in the Arab El-Awamer site. Based on this observation, plants cultivated on last transplanting date in the Ali-Mubarak site have the strongest celery odor. Phthalide compounds, also referred to as odour active compounds, are primarily responsible for celery's distinctive odour (**Macleod *et al*., 1988, Macleod and Ames, 1989, Orav *et al*., 2003 and Turner *et al*., 2021).**

Lund *et al.* (1973) identified hexahy-n-butylphthalide, 3-n-butylphthalide, sedanenolide and β-selinene as exhibiting a celery-like odor. **Van Wassenhove *et al.* (1990)** observed trivial differences in the content of phthalide compounds between growing seasons. **Turner *et al*. (2021)** discovered that monoterpene, sesquiterpene, and phthalide compounds give celery its unique scent and demonstrated that they are significantly affected by maturity.

Table (12). Change of Phthalide compounds as affected by transplanting date in both locations through 2023/2024 season

Site	Ali-Mubarak site				Arab El-Awamer site			
Date / Compounds	Dec.	Jan.	Feb.	Mar.	Dec.	Jan.	Feb.	Mar.
Butylphthalide	-	1.02	0.91	-	6.57	1.40	tr.	-
Sedanenolide	13.80	4.4	3.70	15.31	3.68	-	-	16.87
Apiol	2.37	-	3.31	19.72	-	0.59	4.64	-
Total Phthalides	**16.17**	**5.42**	**7.92**	**35.03**	**10.25**	**1.99**	**4.64**	**16.87**

3.8. Effect of transplanting dates on antioxidant activity and vitamin C in both locations

The quantity of free radical scavenging activity (DPPH) and vitamin C were used to quantify the antioxidant activity of essential oils, data are shown in Table 13. The result clearly showed that location and transplanting date had a strongly effect on both activity of DPPH and the value of vitamin C. Plants grown under Arab El-Awamer conditions contained more significant antioxidant activity and vitamin C content compared with the other condition (Ali Mubarak site).

Furthermore, plants planted in February, included the highest natural active products compared to other transplanting dates, followed by in March date, which indicated that the higher the temperature, the better concentration of antioxidants and vitamin C in plants. The different reduction in results is evident in the different containing of chemical compaction (Table 11).

Kooti and Daraei (2017) mention that celery has substances like caffeic acid, and p-coumaric acid, tannin, saponin, apigenin, ferulic acid, kaempferol, and luteolin, all of which have potent antioxidant properties, to eliminate free radicals. **Takács-Hájos and Borbély-Varga (2014)** reported that stress conditions, including temperature, UV exposure, and sunny periods during the plant vegetation phase, alter secondary assimilation and affecting the synthesis of bioactive molecules. **Evers *et al.* (1997)** who reported that the vitamin C level in celery plants decreased as the nitrogen rate increased.

Table (13). Effect of transplanting date of celery on antioxidant activity and vitamin C in both locations through 2023/2024 season

Date Site	DPPH IC_{50} (µg/ml)		Mean (B)	Vitamin C mg/100g F.W.		Mean (B)
	S1	S2		S1	S2	
December	202.72 b	96.59 e	**149.66 c**	67.70 c	43.26 f	**55.48 b**
January	191.57 c	57.50 g	**124.53 d**	60.13 d	31.11 g	**45.62 c**
February	161.43 d	323.88 a	**242.65 a**	56.41 e	84.72 a	**70.56 a**
March	66.02 f	322.80 a	**194.41 b**	32.01 g	80.83 b	**56.42 b**
Mean (A)	**155.44 b**	**200.19 a**		**54.06 b**	**59.98 a**	
LSD (0.05)						
A	**1.73**			**1.09**		
B	**2.44**			**1.54**		
A X B	**3.46**			**2.18**		

*S1= Ali Mubarak site (sandy soil), S2 = Arab El-Awamer site (calcareous soil). Means followed by the different letters within columns for locations and rows for transplanting dates are significantly varies based on L.S.D. at P ≤ 0.05.

4. Conclusion

The conclusions drawn from this study were:

1) Growth and productivity of *Apium graveolens* L. *var*. secalinum (celery) crops are significantly affected by location, weather, and type of soil that the plants are grown in.
2) Higher growth of the celery crop was obtained under low temperature and sandy soil conditions at the Ali-Mubarak site as compared to higher temperature and calcareous soil conditions at the Arab El-Awamer site.
3) The end of January was the suitable planting time for producing the best growth and chemical composition in both locations.
4) 4.The highest productivity and quality i.e., essential oil, antioxidant activity, and vitamin C content of the celery plant, were enhanced by the higher temperature condition at the Arab El-Awamer site.

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تأثير بعض ظروف النمو على إنتاجية الكرفس المزروع في موقعين مختلفين

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الملخص

أجريت التجارب خلال موسمي ٢٠٢٣/٢٠٢٢ و٢٠٢٤/٢٠٢٣ لتقييم نمو وإنتاجية وجودة نباتات الكرفس خلال أربعة مواعيد للزراعة (ديسمبر ويناير وفبراير ومارس) في موقعين مختلفين في مصر: محطة بحوث علي مبارك بمحافظة البحيرة، والتي تمثل التربة الرملية، ومحطة بحوث عرب العوامر بمحافظة أسيوط، والتي تمثل التربة الرملية الجيرية. كشفت النتائج أن النباتات المزروعة في التربة الرملية في ظروف علي مبارك اعطت نموًا أكبر من تلك المزروعة في التربة الرملية الجيرية في ظروف العوامر. زاد ارتفاع النبات بنسبة ١٤,٩٥٪، وزاد عدد السيقان بنسبة ٥,٩٠٪. وزاد الانتاج بنسبة ٢٣,٣١٪، وكذلك كانت محتويات النيتروجين والفوسفور والبوتاسيوم في نباتات الكرفس أعلى نسبيًا في النباتات المزروعة تحت ظروف علي مبارك مقارنة بالنباتات المزروعة تحت ظروف العوامر. تم الحصول على أعلى كمية من محتوى الكلوروفيل فى النباتات المزروعة في مارس تحت ظروف العوامر، والتي زادت بنسبة ٢٣,١٤٪ مقارنة بالموقع الاخر. تم الحصول على أعلى محتوى للزيوت العطرية بشكل ملحوظ وتحويل الهيدروكربونات إلى مركبات اكسجينية ، إلى جانب تعزيز فيتامين سي ونشاط مضادات الأكسدة،فى النباتات المزروعة في فبراير تحت ظروف العوامر. بينما تم الحصول على أعلى قيمة لمكون الفثاليدات مع النباتات المزروعة تحت ظروف علي مبارك مع آخر مواعيد للزراعة في مارس. يمكن الاستنتاج أن مواعيد الزراعة المثلى لتحقيق أقصى قدر من الانتاج والجودة في الموقعين المدروسين تم تحديدها في يناير. علاوة على ذلك، ظهر موقع علي مبارك كموقع جيد لإنتاج الكرفس، بينما أنتج موقع عرب العوامر محتوى زيت وجودة متفوقين لنباتات الكرفس.